

PRESSURIZED DIRECT CONTACT HEAT EXCHANGE PROCESS.

FIELD OF THE INVENTION

This invention relates to sources, which continuously produce hot pressurized non-condensable gases containing water vapor, and which in combination with a pressurized direct contact heat exchange (Pressurized direct contact heat exchanger) process, continuously convert the energy in these gases into a more useful form, such as steam / electricity.

DESCRIPTION OF THE PRIOR ART

US Patents 3,920,505 and 4,079,585 are previous disclosures relating to heat exchange processes.

Present industrial processes release large volumes of hot non-condensable gases containing water vapor into the atmosphere resulting in a great loss of energy, especially the latent energy of the water vapor. In the case of the combustion of water laden materials or wastes, this results in low thermal efficiencies.

SUMMARY OF THE INVENTION.

A main objective of the present invention is to retain this water within the process and convert it to steam in a more reusable form, and thereby raise the thermal efficiency to a much higher level. This objective is attained by an application of Henry's Law of partial pressures. For example, if the pressure of the gases leaving a pressurized direct contact heat exchanger is 250 psi a (or higher) and the gases are cooled to below 200 degrees F, the water content in the gases would approach 0.10 lbs per lb of dry gas, and the thermal efficiency of the process would approach 90%. The pressure of the steam from the flash evaporator at those gas pressures would approach 70 psia.

The basic embodiment of the invention comprises:

- (a) providing a source which continuously produces hot pressurized non-condensable gases containing water vapor whose given pressure is commensurate with the steam pressure desired in the following flash evaporating step and with the desired overall thermal efficiency
- (b) continuously bringing the hot gases into intimate contact with an aqueous liquid in a pressurized direct-contact heat exchanging process having a hot well, where the gases will flow counter-current to a flow of an aqueous cooler liquid and where water vapor will condense and the gases will become drier, said exchanging process being capable of being divided into at least three

areas / sections; (i) the first is one where the evaporative and heating property of, and part of the condensing and heating property of the water vapor in, the hot gas will be utilized to heat the cooler liquid to the highest temperature it could have when in equilibrium with the hot gases at the given pressure, and thereby cool the hot gases; as well as allow heated liquid and condensed water to collect in the hot well within the area, while still maintaining the highest possible hot well temperature; (ii) the second is one where the gas and liquid will continue to progressively exchange heat content and supply heated liquid to the hot well, until the gas approaches the temperature of the liquid coming from the following flash evaporation step; (iii) and the third is one where the gas and liquid will progressively exchange heat content, until the gas as it cools approaches the temperature of the cool liquid entering at the top of area (iii) and the liquid as it heats approaches the liquid as it heats, approaches the temperature of the liquid from the flash evaporator.

(c) continuously removing heated liquid from the hot well and flash evaporating it in a flash evaporator at a pressure lower than the pressure corresponding to the equilibrium or hot well temperature to thereby (1) convert some of the water in the liquid into steam and (2) cool the liquid to a temperature corresponding to the pressure of the flashed steam and allow it to collect in a sump in the evaporator.

(d) continuously removing cooled liquid from the flash evaporator and re-introducing it to the direct-contact heat exchange section; at a point in area (ii) where the gas in the area is at about the same temperature.

(e) continuously removing the flashed steam from the flash evaporator for further use;

(f) continuously replenishing the cool liquid entering at the top of area (iii) and continuously removing excess liquid from the flash evaporator at an appropriate rate in order to keep the liquid in the exchanger and evaporator in balance; as well as for further use;

(g) continuously removing the cooled gases from the top of zone (iii) for further use.

Other embodiments are discussed herein below

BRIEF DESCRIPTION OF THE DRAWINGS

While, for compactness, the pressurized direct contact heat exchanger is sometimes shown as a single chamber, the various areas could, if desired, be allotted separate chambers. See for example FIGS 9 & 10. For similar reasons, valving and other obvious operations are not shown, or labeled e.g. exhaust steam from the steam turbine could go to a condenser; the turbine compressor in Fig. 3 could be connected directly to the turbine expander, along with a motor electric; An "O" indicates a pump; particulate removers would be installed when they are required, etc.

The following drawings are schematic representations of various embodiments / applications of the present invention:

FIG. 1 illustrates the main embodiment described above together with examples of further use for the flashed steam and cool gases.

FIG. 2 illustrates the situation where a known process (Source) is adapted to produce the gases required for the embodiment shown in FIG. 1

FIG. 3 illustrates an embodiment where the gases from a known process (Source) are passed through a turbine compressor to produce the pressurized hot gases required for the embodiment shown in FIG. 1

FIG. 4 illustrates an embodiment where the liquid from the hot well is heated to a higher temperature indirectly before flashing it in the flash evaporator and wherein the indirect heater could be located within the Source.

FIG. 5 illustrates an embodiment where the pressurized gas-steam mixture is heated prior to going to the Pressurized direct contact heat exchanger.

FIG. 6 illustrates an embodiment where the non-condensable gas content is in the low range and the gases are further pressurized by using a high pressure pump which condenses more of the water vapor prior to going to a secondary pressurized direct contact heat exchanger.

FIG. 7 illustrates an embodiment where combustible material is burnt under the earth or sea and the gases processed above the site in the pressurized direct contact heat exchanger.

FIG. 8 illustrates an embodiment where gaseous material under the earth or sea can be brought above and processed in the pressurized direct contact heat exchanger.

FIG. 9 illustrates an embodiment combining previous embodiments in an overall process, applicable to the pulp & paper industry.

FIG. 10 shows the electrolysis of water under pressure to illustrate a symbiotic relationship in that combining it with the embodiment of FIG. 9 would provide a further symbiotic relationship, in that the paper machine dryers would also contribute further oxygen and steam to the combustion step.

FIG. 11 illustrates an embodiment where a pressurized direct contact heat exchanger is combined with a pressurized indirect contact heat exchanger, located within the source process, to generate high pressure steam, in order to take advantage of the higher efficiency of high pressure, high temperature steam turbines.

FIG. 12 illustrates an arrangement wherein greenhouse gases, such as carbon dioxide can be recycled through its use to accelerate biomass growth and wherein a pressurized direct contact heat exchanger and pressurized combustion is combined with pressurized electrolysis of water to generate pressurized oxygen for the combustion, and hydrogen as a by-product, as well as produce substantially pure carbon dioxide in the flue / exit gases.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following embodiments are process sequences that provide a wide range of choice to fit a wide variety of circumstances, applications and available technologies. Because of the wide range of process variables involved and technologies to choose from it is understood that in most cases, computer simulation would normally be utilized to balance the various variables such as the rate of: recirculation of the hot well liquid; cool liquid supply and excess liquid removal.

The embodiments as illustrated and described is such as to obtain maximum thermal efficiency, noting that, the higher the pressure and the lower the temperature of the gas leaving the pressurized direct contact heat exchanger the higher the thermal efficiency Embodiments involving lower efficiencies are also included.

Referring to the accompanying drawings, the symbols used have the following meaning:

G	Generator for electricity	GT	Gas Turbine
TC	Turbine Compressor	TE	Turbine Expander
PR	Particulate Remover	M	Motor electric

ST	Steam Turbine	C	Condenser
P	Pump	PM	Paper Machine
PDCHE	Pressurized direct contact heat exchanger		
PICHE	Pressurized indirect contact heat exchanger		

Referring to the drawings in greater details, Figure 1 shows the basic embodiment described above. Examples of further use for the flashed steam and cool gases are also shown, namely, as process steam and/or as a source of energy for the production of electricity using steam turbines connected to a generator for the flashed steam, and as a source of energy for the production of electricity using a turbo-expander connected to a generator for the cool gases.

The steam and any excess liquid from the system could also be used to heat large living and business complexes especially in remote places. Further use for the cool gases are described below. Further use for any excess liquid accumulating in the sump / the hot well is also described in various embodiments below.

While the various areas or zones of the pressurized direct contact heat exchanger are shown in one chamber, they could be located in separate chambers or sections. Here the hot well is shown near the top of zone, so as to illustrate that the area below it could be used to dry solid materials. Normally it would be near the bottom.

Various technologies are available in determining how the chambers are constructed and the best type of mixer to use, while maintaining maximum heat exchange and minimum pressure drop, e.g. the field gas scrubber; bubble columns; packed towers; turbo-gas absorber; cascades; collecting the cooler liquid at any point in the pressurized direct contact heat exchanger and recycling it in the exchanger until its temperature approaches that of the gas; etc. While the cooling liquid introduced into areas (I) and (ii) is shown as entering at one point, depending on the mixing technology used, it could be introduced at various points in each area or section.

The whole chamber or any one of the separate chambers could be located within the confines of the Source depending on the process producing the hot gases and other factors. Further elaboration is given in an embodiment below for this and other arrangements.

Existing high pressure process sources include: pressurized combustion projects in the Clean Coal Technology Program sponsored by the US Department of Energy, where pressures in the range of 200 psia are reached; high pressure char oxidation; processing of wood in digesters; etc.

In FIG 2, the source involves a known process which does not provide the pressurized hot gases required of the embodiment of Figure 1, but can be adapted to perform at a substantially elevated pressure and, if feasible, higher temperature.

Examples of the above are:

- (1) Combustion / incineration of materials that produce water vapor, e.g. wet combustibles. While some emphasis is on biomass fuels, the process could have application to the combustion of
 - (a) solid /liquid fossils fuels; especially those having a high sulphur content such that the acidic sulphur gases produced during combustion can be easily removed in the pressurized direct contact heat exchanger (scrubber) step by making the circulating fluid alkaline (see below);
 - (b) fuels intermediate between the two i.e. lignite (brown coal), peat, etc, where the high moisture content is a deterrent to their use; (c) diverse fuels, such as tire derived fuel (TDF), and various sludges, etc. where pollutants can be removed in the pressurized direct contact heat exchanger and concentrated.
- (2) Processes that produce other gases such as Lurgi power gas etc;
- (3) Processes operating in the lower pressure range, where the pressure could be increased. e.g. thermo mechanical pulping of wood chips;
- (4) Diverse processes such the smelting of ores; wet oxidation; chemical and metallurgical processes (blast furnaces), and intermediary operations such as: drying; stripping, extraction; boiling and the like. .

In FIG 3, there is shown an arrangement wherein the increase in pressure and temperature of the source process cannot be carried out, then the gases from the source process are turbo-compressed to the desired pressure, with the temperature increased by the compression. Here where an motor electric drives turbine compressor, in step (g), a turbine expander could be used to drive the compressor. For example in the drying of pulp or paper, enormous quantities of air and steam are expelled to the atmosphere, here the air-steam mixture could be turbo-compressed and their heat content recovered in the pressurized direct contact heat exchanger as is described hereinbelow.

It is also possible that the steps of collecting other non-condensable gases containing water vapor (which are outside of the source) and turbo-compressing them to a pressure sufficient to introduce them into the source process, are added prior to step (a). For example, as shown in FIG 9, the air-steam mixture is added to a high pressure combustion process. Other such mixtures include naturally occurring ones such as fog banks, low clouds, mists, steam eruptions from the earth, etc.

FIG 4 illustrates an arrangement where the liquid from the hot well is heated indirectly to a higher temperature to thereby increase the steam pressure in the flash evaporator. For example, by passing the liquid through a tube bank within the source process, should it be capable of heating the liquid.

FIG 5 illustrates an embodiment where the pressurized gases are further heated prior to going to a pressurized direct contact heat exchanger. For example, by burning oil or gas in the mixture, where it will consume any remaining oxygen or to which additional oxygen may be added. Alternatively, the pressurized gases could be further heated by passing the gases through a tube bank in a hotter zone within the source process.

One can also have the cool gases leaving the pressurized direct contact heat exchanger being heated prior to the turbine expander. For example, by burning oil or gas in the mixture, or by combining the operations of the expander and compressor and introducing inter-stage cooling and heating, as mentioned are in one embodiment below. This may be necessary to avoid water condensing or freezing in the turbine expander, if the pressure is very high and the temperature low.

A further possible arrangement is where, if the pressure and temperature of the hot gases from the source process are high enough, after removing any particulates, they are passed through a gas turbine connected to a generator for electricity to produce electricity, before being sent to the Pressurized direct contact heat exchanger. This is particularly advantageous for a combustion process where high gas temperatures are achievable as illustrated in FIG 9 & 10. If acidic gases are a problem, they may be removed prior to the gas turbine by passing them through a scrubbing chamber using a lime or limestone slurry and particulates might be removed using steam scrubbing and the heat content recovered in the pressurized direct contact heat exchanger. It could be important to dry any wet fuels prior to combustion so as to obtain a maximum temperature. The drying could be done using the gases after leaving the gas turbine as shown in Fig 9.

Oxygen if required in any of the embodiments, is supplied by a source under a pressure greater than the pressure required for the source of the pressurized hot gases. This makes the process more efficient by eliminating the need for a turbine compressor. The electrolysis of water or steam is one such source, where it is more efficient at the higher pressures, with pressurized hydrogen as a valuable by-product. This is illustrated in FIG 10 and expanded below. Alternatively, the oxygen may be supplied in bulk or by air liquefaction with nitrogen as a by-product.

By using cool liquids, containing dissolved or suspended materials as the cooling liquid, the liquid can be concentrated by the recycling of the liquid through the pressurized direct contact heat

exchanger and flash evaporator. Once the concentration of the materials in the circulating liquor reaches the desired level, a portion can be removed at a rate that will prevent further concentration.

If appropriate, the liquid may be used in the source process, e.g. where that process is one of combustion and the material in the liquid is combustible. This is illustrated in FIG 9 & 10. (see below). Other such liquids are effluents from many other mills, as well as from sewage treatment plants.

Other examples would be (a) the desalination of salt water, the liquor would provide a source of salt and the condensed steam a source of salt-free water suitable for irrigation; (b) concentration of dilute sugar sources, i.e. cane, beet and maple sugars, where any residues or forest biomass can be combusted under pressure to produce the hot gases; water associated with oil from the wells (producer water) when separated from the oil can serve as the cool liquid and when concentrated can be added to the oil and burnt and the noncombustible pollutants removed in the ash for proper disposal; etc.

It is also possible that area (i) of step (b) in the embodiment of Figure 1, is used to dry materials. Here all or a portion of the hot gases would be introduced into a chamber containing the material to be dried and the drying done in a number of ways, such as flash drying, a fluidized bed, rotary tumble drier, etc, and the dry or partially dried material removed through a screw press or decompression chambers, etc or sent directly to the Source. Various bio-masses, such as peat, lignite, bark, leaves, branches, roots, and many other materials considered as waste can thus be dried or partially dried. The gases after being so used and before the saturation temperature has been reached, would be sent to the rest of the pressurized direct contact heat exchanger. If the dried material is still considered waste and is combustible and the source process is one of combustion then it can be sent there and consumed. This is illustrated in FIGS 9 & 10.

Undesirable solids and/or gases present in the hot gases and can be removed in the heat exchanger by maintaining the circulating liquid alkaline for acidic gases and acidic for alkaline gases. The substances so formed can then be concentrated and removed from the flash evaporator (see above).

This could allow greater use of fossil fuels containing a high sulphur content. If the solids / gases are very soluble in the water, they could be put through a scrubbing chamber prior to the pressurized direct contact heat exchanger, were a minimum of liquid could reduce their concentration.

Illustrated in FIG 6 is where the non-condensable gas content is in the low range. Here the pressurized hot gases are sent to a primary pressurized direct contact heat exchanger and processed through the first and second areas of step (b) in embodiment A; then they are removed

from the exchanger at a temperature close to that of the temperature of the flashed liquid in the evaporator and fed to the suction side of the pump removing the flashed liquid from the flash evaporator, which is capable of pressurizing this removed mixture to a pressure which will condense most of the steam in this removed gas mixture, this pressurized liquid and gas mixture is then sent to a secondary pressurized direct contact heat exchanger where the liquid and gases separate at a temperature corresponding to that of the pump pressure, the separated liquid in the secondary pressurized direct contact heat exchanger is sent to the top of the primary pressurized direct contact heat exchanger at a point where the removed gases exit, the heat content of the separated gases containing a low amount of steam can then be recovered as desired e.g. in a turbine expander, connected to a generator for electricity, etc.

In certain applications, it is desirable to minimize the presence of the non-condensables in the source process, e.g. in the pressurized thermomechanical pulping of wood chips, by presteaming the chips prior to their entering the refiner.

If the steam from the flash evaporator is unsuitable for a particular use, or cannot be cleaned by conventional means, it is passed through a reboiler for further use.

As illustrated in Fig. 7, where the source process is a combustion process carried out under the earth or sea under pressure and where there is combustible material, the combustion is supported by a pressurized gas containing oxygen and controlled by water piped to the combustion site from above the site. The pressurized hot gases would be piped to a pressurized direct contact heat exchanger above the site and processed utilizing any of the other embodiments that will give the desired result.

Illustrated in Fig 8 is an embodiment, where the source process is carried out below the earth or sea under pressure where there is recoverable material, and where the process is activated by high pressure steam, preferably superheated steam, which allows the material to flow to a pressurized direct contact heat exchanger above the site and processed as for any of the other embodiments.

As illustrated, high pressure super-heated steam could flow down an insulated pipe to melt the methane hydrate ice and allow it and steam to flow up another pipe to the pressurized direct contact heat exchanger above the site to be dried as in FIG 1. Alternatively, the two pipes could consist of concentric inner and outer pipes, with the steam flowing down the inner pipe to melt the hydrate, which will flow up the outer concentric pipe which is wide enough to trap the methane and in which the pressure is less than that of the liberated methane. Some of the methane could be used in a conventional boiler to produce the steam and the water supplied from the hot well. The end product would be a pressurized, substantially dry methane gas. This could also be applicable to number of fossil fuels, e.g. unmineable, gassy coal beds containing methane; wells of natural

gases, volatile oils, etc after the wells have been somewhat depleted; where the steam will act as a sweep gas.

FIG 9 illustrates how a number of the above embodiments can function within the one process, with particular application to the Pulp and Paper Industry where it forms a somewhat symbiotic relationship.

A collector receives air-steam emissions from the paper and pulp mill, especially those from the drier section of the paper machines (other sources not indicated include those from thermomechanical pulping processes). This air-steam mixture, monitored for the correct amount of air required for combustion, is passed through a turbine compressor where it is compressed to a pressure high enough for the process to generate a steam pressure suitable for the dryers of the papermachine, as well as operate a gas turbine e.g. 250 psia and higher. The compressed air-steam mixture goes to the pressure combustion furnace where combustible wet fuels are burnt to produce hot flue gases. Auxiliary fuel, oil or gas, can be added to the hot gases and burnt to maintain uniform combustion and an optimum temperature for the gas turbine. (see above)

These hot gases are passed through a particulate remover and a gas turbine and then through a first section or area (i) of the pressurized direct contact heat exchanger, a drier, which dries biomass material, e.g. forest waste and bark including, liquid concentrate from the flash evaporator, to a moisture content amenable to combustion in the pressure combustion furnace. From the drier the flue gases pass to the main second section or area (ii) of the pressurized direct contact heat exchanger, a scrubber, where they come into intimate contact with a liquid concentrate, containing dissolved and suspended solids from paper & pulp effluents. In applications where only an effluent concentrate is to be combusted or the wet fuels are dry enough to combust, the drier would be omitted and the flue gases would pass directly to the pressurized direct contact heat exchanger. The above concentrate would be generated in the initial start-up of the process as the dilute effluent is concentrated in the flash evaporator.

By continuously removing the heated concentrate and evaporating it in the flash evaporator at a pressure lower than that corresponding to the equilibrium or hot well temperature, so as to (a) convert some of the water in the concentrate into steam, (b) further concentrate the liquid, and (c) cool the concentrate to a temperature lower than the hot well temperature, and then returning the cooled concentrate from the flash evaporator to be reheated in the pressurized direct contact heat exchanger; and removing the steam from the flash evaporator, much of the heat content of the flue gases is converted into process steam.

The saturated flue gases from the main pressurized direct contact heat exchanger, after they are

cooled to approximately the temperature of the liquid concentrate from the evaporator, are passed through the last section or area (iii) of the pressurized direct contact heat exchanger to come into intimate contact with cool dilute effluent to further cool the flue gases and preheat the effluent;

Thus depending on the temperature of the entering effluent and the efficiency of the pressurized direct contact heat exchanger heater, if the pressure of the flue gases is around 250 psi and the water content in the flue gases could be approximately 0.10 lbs per lb of dry flue gas, which is that of the water content of most ambient air, and the thermal efficiency of the process could approach 90% depending on other factors.

Then by continuously removing some of the heated concentrate and adding the required preheated dilute effluent, the proper liquid concentration and balance in the system can be maintained.

The cooled flue gases from the pressurized direct contact heat exchanger heater are passed through a turbine expander to recover some of remaining enthalpy, which is used to compress the air-steam mixture. If necessary they can be put through a particulate remover before going through the turbine expander. Any make-up power for the compression can be supplied by a motor or, while not shown in the drawing, the cooled flue gases can be passed through a combustion chamber in which oil or gas can be burnt to heat the gases to the required temperature before they pass through a turbine expander. (See the above embodiment). Any excess power can be used to generate electrical energy by arranging for the motor electric to also act as a generator for electricity.

To remove any acidic gases from the flue gases, alkaline substances can be added to the liquor circulating in the pressurized direct contact heat exchanger. By a proper choice of substances these will reappear in the ash being removed from the furnace, a portion of which may then be extracted using hot dilute effluent and returned to the pressurized direct contact heat exchanger.

The rest of the drawing illustrates how the water from effluents and the steam in the emissions from the paper and pulp mill is recycled back to mill. The steam from the flash evaporator if necessary is passed through a particulate remover or a reboiler and then sent back to the paper machine dryers, or some used in the pulp mill. Any excess steam can be used to generate electrical energy using condensing steam turbines. The condensate from the dryers is used as clean make-up water at the wet end of the PM. This water reappears again in the white waters from the wet end which are sent to a fiber recovery system, from which they appear in the effluents from that system and are sent to the effluent collector, where they join effluents from the pulp mill. Condensate from the steam turbines can be used similarly in the paper & pulp mill where it will return via the effluents from the mill.

FIG 10 further illustrates how flexible the invention is and that it can even enter into further symbiotic relationships with other processes. One such process is the electrolysis of water under pressure (mentioned in embodiment I above) Electrical energy required for the electrolysis is supplied directly by any generator for electricity adapted to produce the direct current, as converting AC to DC is inefficient. If the pressurized hydrogen, so produced, is not also used in the source process e.g. where CO is produced and this is combined with the H to form methanol, it becomes a very valuable by-product. Alternatively, the oxygen may be supplied as described in I above. If the electrolysis unit is located where further oxygen is required e.g. for pulping and bleaching, this may be a further advantage. Depending on the choice of material being burnt the exit gas will be fairly pure carbon dioxide, another by-product of the process, which has a wide use e.g. for urea, methanol, enhanced oil recovery, refrigeration, etc.

In a further embodiment, energy can be removed from the pressurized direct contact heat exchanger for various purposes, and the resulting cooled liquid returned to the direct contact heat exchanger to be reheated. For example, a primary flash evaporator produces steam at the highest possible pressure level, the flashed liquid from the primary is then flashed in a secondary flash evaporator to produce steam at a lower level, if desired this sequence could be continued or, at any stage, the flashed liquid could be used to indirectly heat other media e.g. hot water heating of a building, with the final cooler liquid returned to the pressurized direct contact heat exchanger for reheating. Similarly, by subdividing the hot well liquid and liquid after flashing and using several independent circulating systems, the rates of circulation, which may depend on the rate of steam production, are not inflexibly tied in with rates and methods of cooling the combustion hot gases.

In an embodiment, the cooled gases from the top of zone (iii) are cooled further, in order to reclaim further latent heat, by bringing them into indirect contact with the cooler gases between expansion stages in the gas expander. This is an example of how inter-stage-cooling and inter-stage-heating could be practiced in a counter-current or parallel arrangement.

One can combine various embodiments wherein the electricity produced is one of direct current which is then fed directly to the electrolysis of water, thereby increasing the efficiency of the overall process. This can also apply to any electricity produced in steps (e) & (g). Similarly, in the case of the electrolysis of steam, the process can supply the direct current as well as the steam.

In some arrangements, advantages of other operations can be made use of in the pressurized direct contact heat exchanger process. For example, transportation of materials by pipeline can often be less expensive than that by land or air. Thus, after the appropriate comminution of the material and its suspension in water, it can be pumped to the primary site, where the wetted material is not a problem and the excess water can be used to cool the gases in pressurized direct

contact heat exchanger and any dissolved / suspended material in the water concentrated in the flash evaporator. This could be very useful for pressure combustion processes, where the combustible material (e.g. coal, peat, and various biomasses) can be transported to the combustion site by pipeline.

Figure 11 illustrates how the pressurized direct contact heat exchanger (pressurized direct contact heat exchanger) is combined with a pressurized indirect contact heat exchanger (pressurized indirect contact heat exchanger), by generating high pressure steam in order to take advantage of the higher efficiency of high pressure, high temperature steam turbines. While the pressurized indirect contact heat exchanger is shown outside the source (for ease of illustration) it would usually be located within the source. While the amount of energy extracted by the pressurized indirect contact heat exchanger will vary depending on the application, a maximum amount would require that enough energy be left in the hot gases in order to operate the pressurized direct contact heat exchanger so the latent energy of the water vapor in the gases can be extracted in the flash evaporator.

While the pressurized indirect contact heat exchanger is shown as a separate chamber outside of the source, it could be located within the confines of the source depending on the process producing the hot pressurized gases. Where the source is a combustion process, the Pressurized indirect contact heat exchanger could consist of tube banks located within the combustion chamber. A pressurized indirect contact heat exchanger can be introduced into anyone of the above embodiments depending on the desired outcome.

In certain circumstances it may be possible to maximize the thermal efficiency further by combining both gas and steam turbine technologies with the pressurized direct contact heat exchanger process, by extracting some of the energy first in a gas turbine, then further energy in a pressurized indirect contact heat exchanger using high pressure steam turbines (as shown above) and finally the remaining energy in a pressurized direct contact heat exchanger using the steam generated there either as process and / or in lower pressure steam turbines. Where the generation of electrical energy is the prime objective, this embodiment could offer the highest thermal efficiency. This could be the case for generation of electricity from coal, especially high sulphur coals. (See previous embodiment)

Another application involves coal bed methane and the sequestering of carbon dioxide, where unmineable, gassy coal beds are swept with pressurized gases containing carbon dioxide which releases the methane and traps the carbon dioxide. The gases containing carbon dioxide are also effective in increasing oil recovery, by reducing its viscosity and providing a driving force towards the wells. The addition of water / steam improves the sweep efficiency and the water can be recovered in the pressurized direct contact heat exchanger.

In these applications, by using the already pressurized gases from the pressurized direct contact heat exchanger the cost of the pressurization of the gases is avoided.

In this technology, while one objective is the removal of the polluting carbon dioxide, in other situations nitrogen is also used to sweep the methane from the coal., so how this application is used could depend on the proportion of carbon dioxide and nitrogen in the gases from the pressurized direct contact heat exchanger as well as the use of the end product of this application, which will be pressurized gases containing methane, e.g. this methane can be used to further heat the hot gases as described above.

The present invention also has application to processes which produce gases which on combustion yield hot pressurized non-condensable gases containing water vapor. The following is an example: a pressurized fluidized-bed gasifier transforms coal into a coal gas containing hydrogen and methane (and carbon monoxide), which after suitable cleaning is combusted with a gas turbine to produce electricity, the hot gases containing water vapor exit the turbine at a pressure sufficient to operate the pressurized direct contact heat exchanger and produce low pressure steam as well as operate a pressurized indirect contact heat exchanger which can supply high pressure steam to the gasifier, as illustrated in embodiment W above, Whether or not the pressurized indirect contact heat exchanger produces steam for high pressure steam turbines is a separate consideration. In present systems, the hot gases from the turbine are sent to a conventional heat recovery steam generator, so that the energy in the water vapor is lost to the atmosphere.

FIG. 12 illustrates a way to reduce greenhouse gases, where a pressurized direct contact heat exchanger (pressurized direct contact heat exchanger) and pressurized combustion is combined with pressurized electrolysis of water to generate pressurized oxygen for the combustion, and hydrogen as a by-product. This produces substantially pure carbon dioxide in the flue / exit gases, which is used to accelerate biomass growth in a confined or enclosed space (e.g. an inflated plastic covering, see "solar tower" below). Low pressure steam from the flash evaporator can be to heat the enclosed space. Part of the carbon dioxide can also be combined with ammonia to make compounds such as urea, which can also be used to accelerate biomass growth as urea. By creating a false ceiling below the canopy or covering over the enclosed space, the oxygen and water vapour, generated by the biomass, being lighter than the carbon dioxide, can be segregated and removed and used in the pressurized direct contact heat exchanger process (and the carbon dioxide recycled to the enclosed space or "greenhouse ") Some or all of the biomass can be used for combustion / human consumption and any waste from the latter use can be recycled through the combustion cycle.

If air liquefaction is used in place of or in addition to water electrolysis to produce the pressurized

oxygen then the nitrogen from the liquefaction can be used along with the hydrogen (in case of the latter) to produce ammonia which can then be used to produce the urea.

A further symbiotic situation is where the above is combined with EnviroMission 's (Australian firm) "solar tower" (a vertical wind farm) where a chimney, connected to and surrounded by a shallow, circular, acrylic greenhouse, (7km in diameter) will provide sufficient draft, for the hot air generated by the greenhouse, to power turbo-generators to produce electricity.

A special embodiment is as follows: fuel cell takes in hydrogen and a gas containing oxygen and generates electricity and expels hot gases laden with water vapour. By operating the fuel cell at elevated pressures and passing the hot gases through the pressurized direct contact heat exchanger the efficiency of the cell is increased. If the gases are not hot enough, pressurized combustible gases / oil can be burnt within the gases to increase their temperature and consume any remaining oxygen or they can be heated by any of the methods described above.

The preceding description of the invention is merely exemplary and is not intended to limit the scope of the present invention in any way thereof.